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FIVE YEARS OF ANTARCTIC RESEARCH

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Antarctic discovery and research tend to progress by fits and starts. In four years JAMES COOK disproved the myth of a fertile southern continent. After half a century, renewed activity during the period 1819–1843 saw the main outlines of the continent appear on the map, thanks to hardy navigators and scientists of four major nations. A further half century elapsed before scientific expeditions started to winter in the Antarctic and make the first tentative dashes into the interior. After another half century of piecemeal probing into the interior, filling in the gaps in the coastline and developing new techniques of Antarctic research and exploration, the increasingly respected and affluent position of science in the major world communities made it possible to attack many polar and geophysical problems on a co-ordinated basis through the medium of the International Geophysical Year. The five years from 1956 to 1961 have seen nations, men and money involved in Antarctic research on an unprecendented scale, and the rewards of new knowledge gained have accumulated rapidly.

The call from the ICSU Special Committee for the International Geophysical Year (CSAGI) for the development of a large Antarctic programme did not come at a particularly opportune time from the political point of view. Great Britain, Argentine and Chile were embroiled in a bitter argument over Antarctic sovereignty, and the outlook of the USSR and USA on world problems rarely coincided. Nevertheless from the first CSAGI Antarctic Conference in June 1955, a desire among scientists to work together and avoid political controversy was evident so that difficulties which might have hindered a co-operative effort in Antarctica were largely avoided.

The unprecedented scale of effort in Antarctic research is well illustrated by the fact that nine wintering stations were established in inland regions during one or both of the IGY years, compared with the previous total of one man who had spent one winter a few tens of miles in from the coast. Extensive oversnow traverses and aircraft flights have now sighted the major part of the 12,000,000 km^2 of the continent and surrounding ice-shelves. Only one major gap remains to be seen, namely an area of more than 1,000,000 km^2 between the South Pole and the Antarctic coastline between the meridians of 20° W and 60° E. Elsewhere we have at least an approximate idea of the surface contours of the vast ice sheet covering this continent. We have even a rough idea of the form of the rock surface beneath the ice. A great deal has been learned about the climate of the continent, both at the surface and in the high atmosphere, while at still greater heights our knowledge of aurora and the ionosphere over Antarctica has made considerable strides. Although much remains to be discovered it is clear that the past five years have seen the unveiling of many of Antarctica's most interesting physical phenomena.

The development of Antarctic research during the IGY was so successful that the International Council of Scientific Unions decided that they should give every encouragement to the continuation of an international programme in Antarctica after the conclusion of the International Geophysical Year. The Special Committee on Antarctic Research (SCAR) was set up for this purpose and international co-ordination of Antarctic programmes is still continuing under the auspices of ICSU on this basis. It is impossible to do more than pick out a number of highlights of the achievements of the past five years in the different disciplines. The following paragraphs make some attempt at this but the time is still too close to assess which of these will be of greatest importance in the future.

Meteorology

The IGY objective of making co-ordinated studies of geophysical phenomena over the earth has perhaps had no greater success than the setting up of a synoptic network of well-spaced surface and upper atmosphere stations over the antarctic continent. This network has continued in operation from 1957 to the present time at practically full strength. Where formerly only intermittent data and tentative ideas on antarctic weather systems were available there is now a very great volume of information and well documented studies. The general circulation of the atmosphere over Antarctica both in the stratosphere and the trophosphere are reasonably well understood. In the Antarctic stratosphere during the winter months a great circumpolar vortex cuts off the air above the continent for a considerably longer period than in the corresponding case of the Arctic. Lack of solar heating results in very low stratospheric temperatures towards the end of the winter. However during the summer the continuous sunshine results in the stratosphere warming up to similar temperatures to those that occur over the Arctic. The annual stratospheric temperature range of some 50° to 60° C is not however matched in the troposphere where continuous exchange of air with warmer latitudes takes place throughout the year, particularly during the winter months when intense cooling causes great cyclonic activity around the continent. The intensity of surface cooling is not paralleled anywhere else on earth. Temperatures as low as $-86°$ C (-125 ° F) have been recorded at the Russian Vostok station which is somewhat colder than the South Pole station. The very cold surface layers of air pour down any appreciable surface slopes causing intense katabatic winds, particularly in the peripheral zone of the ice sheet. Experimental results and theoretical studies have thrown considerable light on the nature of these intense winds. Other meteorological investigations include numerous studies of the radiation balance, of the distribution of ozone in time and space, and measurements of the concentration of carbon dioxide in the atmosphere. The latter two fields illustrate the world-wide importance of some antarctic results. The pattern of variation in the ozone concentration over Antarctica differs from that over the Arctic and presents a problem of broad geophysical significance. On the other hand, the small seasonal change of carbon dioxide concentration makes Antarctica a much more satisfactory testing ground for detection of secular change in the total carbon dioxide content of the atmosphere than any northern hemisphere station where large seasonal variations make the detection of small secular changes much more difficult.

Since 1957 weather analyses over the antarctic continent and southern hemisphere have been made on an international basis, first at the antarctic weather central at Little America "V" station in Antarctica during the Geophysical Year and subsequently at the International Antarctic Analysis Centre established in Melbourne where representatives of four nations now work together on this problem. The success of the meteorological programme has been such that the largest problems to be solved on general circulation in the southern hemisphere are now due to the lack of observations over the southern oceans rather than in the highest southern latitudes. It is hoped that new techniques, such as automatic weather reporting stations, either drifting or anchored in the southern ocean, and weather observations from satellites may do much to solve these problems during the coming years.

Geomagnetism

The IGY network of magnetic observatories in Antarctica has now been in operation for a sufficient length of time to show that the largest secular change in the earth's magnetic field is taking place in Antarctica over a region centred near the meridian of Greenwich a thousand miles or so from the geographical south pole. The rate of change of the vertical component of the magnetic field here is about three times as large as any known elsewhere on earth. Associated with the same region is the largest departure of the actual magnetic field from that which would be present if the earth behaved as a simple magnetic dipole. Apart from the usefulness of these results in studying theories of the earth's magnetism in relation to possible electromotive forces generated by convective currents in the earth's core, the region provides a particularly useful testing ground for sorting out whether certain factors are controlled by the local or dipole geomagnetic field. Recording of the more rapid geomagnetic fluctuations has also provided the basis for varied studies of upper atmosphere physics.

Upper atmosphere physics

Now that vast sums are being spent on the exploration of space surrounding the earth, it is important that related observations which can be made at little expense from the surface of the earth should not be neglected. Auroral, ionospheric, cosmic ray and geomagnetic measurements in polar regions all fall into this category. Some such investigations may be clarified by results from one hemisphere only, in which case the civilised regions of the northern hemisphere usually provide better facilities for research. However studies such as the simultaneity of auroral displays in the two hemispheres, the propagation of very low frequency radio waves (whistlers) from one hemisphere to another, the similarities of auroral zones of the two hemispheres and the relative effect of the local and dipole fields on auroral arcs in the large geomagnetic anomaly of Antarctica have all yielded results which could not have been obtained if observations were largely confined to the northern hemisphere, as was the case during the first and second Polar Years.

The establishment of a permanent ionospheric station at a geographical pole is more practicable on the Antarctic ice sheet than on the drifting ice of the Arctic ocean. Results from the south pole and other high latitude Antarctic stations provide data from a region where the ionosphere is in the shadow of the earth during the winter months. Even without ionizing radiation from the sun, considerable ionization continues over the South Pole and surrounding stations during the dark period. Such ionization occurs as the result of drift from lower latitudes. The results therefore throw fresh light on the stability of such ionization when combined with measurements of the speed of drift which have been made by various techniques. The results of the IGY have interested ionospheric physicists so much that a second wave of activity appears to be developing in this field as analyses of IGY data suggest further experiments.

Glaciology

Before moving on to a discussion of crustal geophysics the extensive ice-sheet covering practically the whole continent of Antarctica and various parts of the surrounding seas warrants special mention. Explorations since the discovery of Antarctica have all contributed something to our knowledge of the extent and form of this vast ice-sheet which rises to a dome some 4,000 m above sea level in East Antarctica while in West Antarctica it attains an elevation slightly over 2,000 m. Prior to 1956 the only extensive study of the thickness of this ice had been made by the Norwegian–British–Swedish Antarctic Expedition along a profile some 600 km long from the coast onto the edge of the high antarctic plateau. Since 1956 oversnow traverses totalling over 15,000 km have carried out systematic exploration both of the nature of this ice-sheet near the surface and of the depth of ice over the continent. The mean thickness has been shown to be around 2,000 m or more, which is appreciably larger than most estimates before the IGY.

Studies of the mass balance of the Antarctic ice sheet as a whole have now reached the stage where most estimates of the total annual accumulation of snow and ice lie within the range of 0.9 to $2.6 \cdot 10^{18}$ grams. The lower figure has been obtained from meteorological analyses of water vapour transport over and out of the continent while the higher figure depends on the annual net accumulation of snow determined from stake and pit studies. Estimates on the debit side made during the past five years put the total losses between 0.52 and $2.21 \cdot 10^{18}$ grams. The majority favour the view that the Antarctic ice sheet is now increasing in volume, but more measurements of ice discharge are needed before sound conclusions can be reached. Although these estimates lack accuracy, one must recall that in 1955 results from which to estimate the mass balance of Antarctica were almost non-existent.

Crustal studies

The seismological network which has been in operation since 1957 has shown that the seismicity of the Antarctic continent is small. However, the network has been very useful in studying larger earthquakes outside the continent. A number of earthquakes in the southern Indian Ocean seismic belt have been located only by Antarctic stations while Antarctic data has frequently been of use in the accurate location of distant earthquakes. One important application of the study of surface waves from earthquakes has been the determination of crustal thicknesses over Antarctica. In general these average over 30 km in East Antarctica, but are a little less in West Antarctica. Gravitational studies lead to similar conclusions, while the geological evidence as far as it is available is consistent. East Antarctica has been shown to be typical of a large continental mass, consisting of pre-cambrian basement rocks overlain by various sedimentary beds into which igneous sills and dykes have been injected. The rocks of the peninsula of West Antarctica are considerably younger and correspond to those of the Andean mountain chain, while in other sections of West Antarctica volcanic rocks are common. If the ice sheet melted, it seems that West Antarctica would be seen to consist of a series of islands.

Oceanography

Antarctic oceanography has suffered to some extent over recent years through being a secondary activity to the main task of transporting men and material to their wintering stations. Ship-borne investigations throughout winter and early spring have not been attempted in recent years on a scale similar to that of the earlier Discovery investigations, but a considerable volume of work has been accomplished nevertheless. Detailed soundings by Soviet ships have located long trenches parallel to the coastline in the continental slopes. American icebreakers have penetrated to the coast of the Bellinghausen Sea, surpassing Cook's furthest south latitude of 71° 10′ in this sector, a record which has stood since 1774. They found a relative paucity of biological life in these waters presumably due to the effect of the heavy and stagnant pack ice cover of this region. Routine deep temperature and salinity soundings have been made by several ships and some ^{14}C dating of deep waters has been done.

Cartography

Cartography, like geological and biological sciences, had no official place in the Antarctic programme of the IGY, so its formal status as a field of international collaboration in Antarctic research dates from the start of 1959 when SCAR became responsible for a wider field of research. Mapping is so important to many scientific studies that much was accomplished on a national basis before and during the IGY. Recognition by SCAR has improved the exchange of maps and mapping information, and is helping to avoid duplication of effort. However the mapping of 12,000,000 km^2 of relatively featureless snow will take a long time, even on a reconnaissance basis.

Biology

Although some countries have undertaken research on Antarctic biology for many years, such studies were naturally not given major support during the IGY. Since 1959 SCAR has endeavoured to encourage biological investigations, both marine and terrestrial, and there appears to be some increase in this sphere. A biological laboratory has been built at MacMurdo by the United States and other countries are considering similar efforts, but in the absence of a major stimulus along the lines of the IGY it seems to the non-biological observer that it will be a long time before Antarctic biology is exploited on a scale warranted by the opportunities.

On the human side, the presence of medical officers on expeditions has resulted in a steady stream of work on human physiology, which has recently been augmented by the work of professional physiologists on Antarctic expeditions. It appears, however, that apart from the extremities, human beings use their clothing to maintain much the same microclimate close to the skin when in Antarctica as that which they enjoy in more temperate climates. One may imagine that the isolated life would provide a fertile field for psychological investigations, but the hardy Antarctic man is believed to be less co-operative towards the probings of psychologists than he is towards the physiologist's instruments.

Although human beings have been relatively unrewarding for physiological studies, similar work which has been done on dogs, penguins, seals and fishes promises results of considerable value on the adaption of biological mechanisms to cold environments.

The future

A great deal remains to be done to complete the straightforward exploration of the interior of the continent, and to collect sufficient data for the thorough analysis of scientific problems at present under investigation. More fields needing investigation are apparent, and no doubt current work will reveal further horizons. So long as Antarctic expeditions continue to concentrate on fields of study which cannot be undertaken at less cost in more accessible lands, support for such efforts will be justified. Even so the general public and governments may tend to look for direct financial returns on their Antarctic investments in terms of rich mineral deposits or other forms of wealth. Such returns may not be impossible, but it would seem a short sighted policy to stress this aspect too much in obtaining support for long term investigations. Although its value may not always be obvious, Antarctic research must clearly be viewed as offering the type of return one may expect from pure rather than applied science. By adding to the whole field of physical and biological knowledge of our globe, Antarctic research may well help to uncover some basic truths.

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